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Received December 11, 1766.

XI. *Experiments on* Rathbone-Place *Water*: *By the Hon.* Henry Cavendiſh, *F. R. S.*

Read Feb. 19, 1767.

DR. Lucas has given a ſhort examination of this water in the firſt part of his treatiſe of waters. It is the produce of a large ſpring at the end of Rathbone-place, and uſed a few years ago to be raiſed by an engine for ſupplying part of the town. The engine is now deſtroyed; but there is a pump, nearly in the ſame ſituation, which yields the ſame kind of water. It is the water of this pump, which was uſed in theſe experiments.

Moſt waters, though ever ſo tranſparent, contain ſome calcareous earth, which is ſeparated from them by boiling, and which ſeems to be diſſolved in them without being neutralized by any acid, and may therefore not improperly be called their unneutralized earth. The following experiments were made chiefly with a view of enquiring into the cauſe of the ſuſpenſion of this earth, for which purpoſe this water ſeemed well adapted; as it contains more unneutralized earth than moſt others.

Theſe experiments were made towards the latter end of September 1765, after a very dry ſummer; whereby the water was moſt likely more impregnated with ſaline and other matters than it uſually is.

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The water, at the time I uſed it, looked rather foul to the eye. On expoſing ſome of it for a few days to the open air, a ſcurf was formed on its ſurface, which was nothing elſe but ſome of the unneutralized earth ſeparated from the water. On dropping into it a ſolution of corroſive ſublimate, it grew cloudy in a few ſeconds; it quickly became opake, and let fall a ſediment. This is a property, which I believe does not take place, in any conſiderable degree, in moſt of the London waters.

EXPERIMENT I.

494 ounces of this water were diſtilled in a copper ſtill, till about 150 oz. were drawn off. A good deal of earth was precipitated during the diſtillation, which being collected and dried, weighed 271 grains. It proved to be entirely a calcareous earth, except a ſmall part, which was magneſia. This I found in the following manner. A little of this earth, being mixed with ſpirit of ſalt, diſſolved entirely; which ſhews it to conſiſt ſolely of an abſorbent earth, but does not ſhew whether it is a calcareous earth or magneſia. The remainder was ſaturated with oil of vitriol: a great deal of matter remained undiſſolved, which, as the earth was ſhewn to be entirely of the abſorbent kind, muſt have been ſelenite, or a calcarious earth ſaturated with the oil of vitriol. The clear liquor ſtrained from off the ſelenite yielded on evaporation only eighteen grains of ſolid matter, which proved to be Epſom ſalt; ſo that all the earth, except that contained in the eighteen grains of Epſom ſalt, muſt have been of the calcareous kind. That contained in the Epſom ſalt is well known to be magneſia.

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The water remaining after diſtillation, and from which the earth was ſeparated, was evaporated, firſt in a ſilver pan, and afterwards in a glaſs cup, till it was reduced to about three ounces. Not the leaſt earth was precipitated during the evaporation, till it was reduced to a ſmall quantity; there then fell 39 grains, which were entirely ſelenite: ſo that all the unneutralized earth in the water was ſeparated during the diſtillation. The liquor thus evaporated was of a reddiſh colour, like an infuſion of ſoot.

Many waters contain a good deal of neutral ſalt compoſed of the nitrous acid united to a calcareous earth; the moſt convenient way of aſcertaining the quantity of which, is to drop a ſolution of fixed alcali into the evaporated water, till all the earth is precipitated; whereby this ſalt is changed into true nitre, and is capable of being cryſtallized. For this reaſon, ſome fixed alcali was dropt into the evaporated water till it made no farther precipitation. The earth precipitated thereby weighed thirty-ſix grains, and was entirely magneſia. The liquor was then farther evaporated, but no nitre could be made to ſhoot: being then evaporated to dryneſs, it weighed 256 grains. It gave not the leaſt ſigns of containing any nitrous ſalt, either by putting ſome of it upon lighted charcoal, or by making a match with a ſolution of it, but appeared to be a mixture of ſea ſalt and vitriolated tartar, or ſome other ſalt compoſed of the vitriolic acid. As I have heard of no other London water, that has been examined with this view, but what has been found to contain a conſiderable proportion of nitrous ſalt, it ſeems very remarkable that this ſhould be intirely deſtitute of it. I now

proceed

proceed to the experiments made on the diſtilled water.

The diſtilled water, eſpecially that part of it which came over firſt, became opake, and let fall a precipitate, on droping into it a ſolution of ſugar of lead. It alſo became opake by the addition of corroſive ſublimate, much in the ſame manner that the plain water did before diſtillation.

It was found, by dropping into it a little acid of vitriol and committing it to evaporation, to contain a ſmall quantity of volatile alcali; as it left four grains of a browniſh ſalt, which being re-diſſolved in water, yielded a ſmell of volatile alcali on the addition of lime. It is doubtleſs this volatile alcali, which is the cauſe of the precipitate, which the diſtilled water makes with ſugar of lead and corroſive ſublimate.

What firſt ſuggeſted to me that the diſtilled water contained a volatile alcali, was the diſtilling ſome of it over again in a retort; whereby the firſt runnings were ſo much impregnated with volatile alcali, as to turn paper died with the juice of blue flowers, to a green colour, and in ſome meaſure to yield a ſmell of volatile alcali.

In the foregoing experiment, the ſalt procured from the diſtilled water was perfectly neutral; ſo that the quantity of acid employed was certainly not more than ſufficient to ſaturate the alcali, but it may very likely have been leſs; as in that caſe the ſuperfluous volatile alcali would have flown off in the evaporation. The following experiment ſhews pretty nearly the quantity of volatile alcali in the diſtilled water.

EXPERI-

Experiment II.

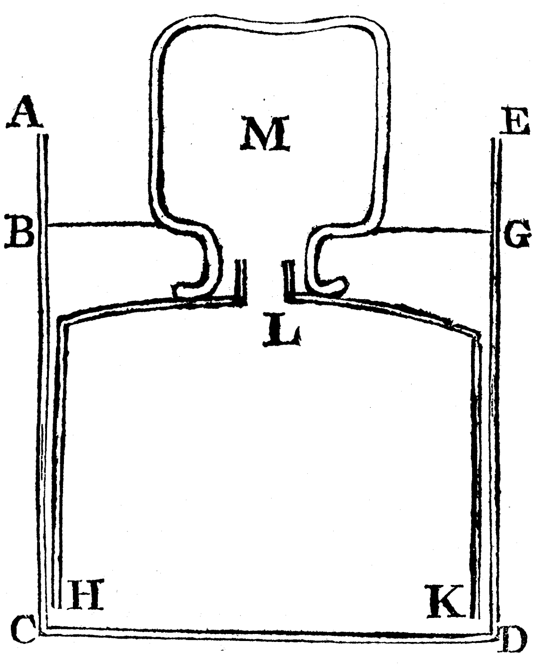
1128 ounces of Rathbone-place water were diſtilled in the ſame manner as the former. The diſtilled water was divided into two parcels, that parcel which came over firſt weighing 121 ounces, the other 146. A preparatory experiment was firſt made, in order to form a judgement of the comparative ſtrength of each parcel, and alſo of the quantity of acid which it would require to ſaturate them. This was done by dropping ſugar of lead into each parcel till it ceaſed to make a precipitate. It was judged from hence that the firſt parcel contained about $2\frac{1}{2}$ times as much volatile alcali as an equal quantity of the ſecond. Into 30 ounces of the firſt parcel, mixed with as much of the ſecond, was then put 43 grains of oil of vitriol, which was ſuppoſed to be about $\frac{1}{2}$ more than ſufficient to ſaturate the alcali therein. The mixture was then evaporated. When reduced to a ſmall quantity, it was found to be rather acid: ſixteen grains of volatile ſal ammoniac were therefore added, which ſeemed nearly ſufficient to neutralize it. Being then evaporated to dryneſs, it left ſixty-ſix grains of a browniſh ſalt, which diſſolved readily in water, leaving only a trifling quantity of brown ſediment. A little of this ſalt was found to make no precipitate on the addition of fixed alcali, and the remainder, being boiled with lime, was converted into ſelenite; a ſure ſign that the ſalt was merely vitriolic ammoniacal ſalt. The volatile alcaline ſalt contained in ſixty-ſix grains of vitriolic ammoniacal ſalt is $58\frac{1}{2}$ grains; from whence deducting ſixteen grains, the weight of the volatile ſal ammoniac added, it appears that the diſtilled

water

water uſed in this experiment contains $42\frac{1}{2}$ grains of volatile ſalt; and therefore the whole quantity of volatile ſalt driven over by diſtillation ſeems to be about ſixty-eight grains, which, as the ſecond parcel was ſo much weaker than the firſt, is probably nearly the whole volatile alkali contained in the water.

Experiment III.

Dr. Brownrig, in a paper printed in the Philoſophical Tranſactions, for the year 1765, ſhews that a great deal of fixed air is contained in Spa water. This induced me to try whether I could not find any in that of Rathbone-place; which I did by means of the contrivance repreſented in the drawing.



ACDE reprefents a tin pan, filled with Rathbone-place water as high as BG. HKL is another tin pan, within the firft, in the manner of an inverted funnel, and made in fuch a manner as to leave as little room as poffible between that and the fides of the outward veffel. M reprefents a bottle, full of the fame water, inverted over the mouth of the funnel. By this means, as faft as the air is difengaged by heat from the water within the funnel, it muft neceffarily rife up into the bottle. The Rathbone-place water, put into the veffel, weighed 411 ounces, the funnel held 353 ounces. A bottle full of water being inverted over the mouth of the funnel, as in the figure, the water was heated, and kept boiling about $\frac{1}{4}$ of an hour. As foon as one bottle was filled with air, it was removed by putting a fmall ladle under its mouth, while under water, and fet with its mouth immerfed in the fame manner in another veffel of water, taking care not to fuffer any communication between the included air and the outward air during the removal. At the fame time, another bottle full of water was inverted over the mouth of the funnel, in the fame manner as the former. It was not eafy telling how much air was difcharged from the water; as the air in the bottles, when firft removed, was hot and expanded; and, before I could be fure it was cold, there was fome of it abforbed by the water: but there feemed to be above 75 ounce meafures difcharged, fcarce twenty of which arofe before the water began to boil. The water continued difcharging air after the experiment was difcontinued. In about a day's time, much the greateft part of the air was abforbed, fcarce fixteen u nce meafures remaining. That which was abforbed appeared to be fixed air, as the water which had

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abſorbed it made a precipitate with lime-water. But, in order to abſorb all the fixed air more perfectly, the air which remained not abſorbed was transferred into another bottle of water, in the manner deſcribed in my firſt paper on factitious air, page 142 of the preceding volume. This bottle was then ſet with its mouth immerſed in a bottle of ſope-leys; after which, by ſhaking the bottle, the ſope-leys was mixed with the included water; whereby the air in the bottle was brought in contact with the ſope-leys, which is well known to abſorb fixed air very readily. By this means the air was reduced to $8\frac{1}{4}$ ounce meaſures. A ſmall vial being filled with equal quantities of this and inflammable air, and a piece of lighted paper applied to its mouth, it went off with as loud a bounce, as when the ſame vial was filled with equal quantities of common air and inflammable air. The ſpecific gravity of the remainder was tried by a bladder, in the manner deſcribed in the above-mentioned paper; as well as could be judged from ſo ſmall a quantity, it was juſt the ſame as that of common air. From theſe two circumſtances, I think we may fairly conclude that this unabſorbed part was intirely common air; conſequently the air diſcharged from the Rathbone-place water conſiſted of $8\frac{1}{4}$ ounces of common air and about 66 of fixed air. The air which was diſcharged before the water began to boil contained much more common air, than that which was diſcharged afterwards; that which was diſcharged towards the latter end ſeeming to contain ſcarce any but fixed air.

As ſo much fixed air is diſcharged from this water by boiling, it ſeemed reaſonable to ſuppoſe, that the diſtilled water ſhould contain fixed air. I accordingly found it to make a precipitate with lime-water.

Experiment IV.

The following experiment ſhews that the fixed air was not generated during the boiling, but was contained in the water before. Into 30 ounces of Rathbone-place water was poured ſome lime-water, which immediately made a precipitate. More lime-water was added, till it ceaſed to make any farther precipitate. It required 2c$\frac{1}{4}$ ounces. The precipitated earth being dried weighed 39 grains.

The unneutralized earth contained in 30 ounces of Rathbone-place water is 16$\frac{1}{2}$ grains, and the earth contained in 20$\frac{1}{4}$ ounces of lime-water (as was found by precipitating the earth by volatile ſal ammoniac) is 21 grains. Therefore the earth precipitated from the mixture of Rathbone-place water, and lime-water, is about equal to the ſum of the weights, of the earth contained in the lime-water, and of the unneutralized earth in the Rathbone-place water; and conſequently all the unneutralized earth ſeems to be precipitated from Rathbone-place water by the addition of a proper quantity of lime-water. But a more convincing proof that this is the caſe, is that the clear liquor, after the precipitate had ſubſided, did not depoſit any earth on boiling, or become in the leaſt cloudy on the addition of fixed alkali; whereas Rathbone-place water in its natural ſtate becomes opake thereby. It might perhaps be expected, that the clear liquor ſhould ſtill make a precipitate on the addition of fixed alkali, though the unneutralized earth is precipitated; as in all probability there is ſtill a good deal of earth remaining in it in a neutralized ſtate. The reaſon why it does not, ſeems to be, that the remaining earth is moſt likely intirely magneſia; and Epſom

ſalt,

falt, when diffolved in a great quantity of water, does not make any precipitate on the addition of fixed alkali.

There is great reafon to fuppofe that the earth precipitated on mixing the Rathbone-place water and lime-water, was very nearly faturated with fixed air, i. e. that it contained very near as much fixed air, as is naturally contained in the fame quantity of calcarious earth. If fo, 30 ounces of Rathbone-place water contain as much fixed air as 39 grains of calcarious earth; whereas the unneutralized earth, in that quantity of water, is only 16 $\frac{1}{2}$ grains; fo that Rathbone place water contains near 2 $\frac{1}{3}$ times as much fixed air as is fufficient to faturate the unneutralized earth in it.

It feems likely from hence, that the fufpenfion of the earth in the Rathbone-place water, is owing merely to its being united to more than its natural proportion of fixed air; as we have fhewn that this earth is actually united to more than double its natural proportion of fixed air, and alfo that it is immediately precipitated, either by driving off the fuperfluous fixed air by heat, or abforbing it by the addition of a proper quantity of lime water.

Calcareous earths, in their natural ftate, i. e. faturated with fixed air, are totally infoluble in water; but the fame earths, entirely deprived of their fixed air, i. e. converted into lime, are in fome meafure foluble in it; for lime-water is nothing more than a folution of a fmall quantity of lime in water. It is very remarkable, therefore, that calcareous earths fhould alfo be rendered foluble in water, by furnifhing them with more than their natural proportion of fixed air, i. e. that they fhould be rendered foluble, both by depriving them of their fixed air,

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and by furnifhing them with more than their natural quantity of it. Yet, ftrange as this may appear, the following experiments, I think, fhew plainly that it is the real cafe.

Experiment V.

In order to fee whether I could fufpend a calcareous earth in water, by furnifhing it with more than its natural proportion of fixed air, I took 30 ounces of rain water, and divided it into two parts: into one part I put as much fpirit of falt, as would diffolve 30 $\frac{3}{10}$ grains of calcareous earth, and as much of a faturated folution of chalk, in fpirit of falt, as contained 20 grains of calcaroeus earth: into the other part I put as much fixed alkali, as was equivalent to 46 $\frac{8}{10}$ grains of calcareous earth, i. e. which would faturate as much acid. This alkali was known to contain as much fixed air as 39 grains of calcareous earth. The whole was then mixed together and the bottle immediately ftopped. The alkali was before faid to be equivalent to 46 $\frac{8}{10}$ grains of calcareous earth, and was, therefore, fufficient to faturate all the fpirit of falt, and alfo to decompound as much of the folution of chalk as contains 16 $\frac{1}{2}$ grains of earth. This mixture, therefore, fuppofing I made no miftake in my calculation, contained 16$\frac{1}{2}$ grains of unneutralized earth, with as much fixed air as is contained in 39 grains of calcareous earth; which is the quantity which was found to be in the fame quantity of Rathbone place water. The mixture became turbid on firft mixing, but the earth was quickly re-diffolved on fhaking, fo that the liquor became almoft tranfparent. After ftanding fome time, a flight fediment fell to the bottom, leaving the liquor perfectly

tranſparent. The mixture was kept three or four days ſtopped up, during which time it remained perfectly clear, without depoſiting any more ſediment. The clear liquor was then poured off from the ſediment, and boiled for a few minutes, in a Florence flaſk; it grew turbid before it began to boil, and diſcharged a good deal of air; ſome earth was precipitated during boiling, which being dried weighed 13 grains.

This ſhews that there was really, at leaſt 13 grains of earth ſuſpended in this mixture, without being neutralized by any acid; the ſuſpenſion of which could be owing only to its being united to more than its natural proportion of fixed air. But, as a further proof of this, I made the following experiment.

Experiment VI.

I took the ſame quantities of rain water, ſolution of chalk, ſpirit of ſalt, and fixed alkali, as in the laſt experiment, but mixed them in a different order. The fixed alkali was firſt dropped into the ſpirit of ſalt, and when the effervеſcence was over, was diluted with $\frac{1}{2}$ the rain water. The ſolution of chalk was then diluted with the remainder of the rain water, the whole mixed together, and the bottle immediately ſtopped, and ſhook vehemently. A precipitate was immediately formed on mixing, which could not be re-diſſolved on ſhaking.

It muſt be obſerved, that, in the firſt of the two foregoing experiments, all the fixed air contained in the alkali was retained in the mixture, none being loſt by effervеſcence; whereas, in the laſt experiment, the greateſt part of the fixed air was diſſipated in the effervеſcence; no more being retained than

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what was contained in that portion of the fixed alkali, which was not neutralized by the acid; and consequently the unneutralized earth, in the mixture, contained not much more fixed air than what was sufficient to saturate it. As the latter of these mixtures differed no otherwise from the former, than that it contained less fixed air; the suspension of the earth in the former must necessarily be owing to the fixed air.

In the two foregoing experiments the water contained, besides the unneutralized earth, and fixed air, some sal sylvii, and a little solution of chalk in the marine acid; which, it may be supposed, contributed to the suspension of the earth: but the following experiment shews that a calcarious earth may be suspended in water, without the addition of any other substance than fixed air.

Experiment VII.

A bottle full of rain water was inverted into a vessel of rain water, and some fixed air forced up into the bottle, at different times, till the water had absorbed as much fixed air as it would readily do; 11 ounces of this water were mixed with 6 $\frac{1}{2}$ of lime water. The mixture became turbid on first mixing, but quickly recovered its transparency, on shaking, and has remained so for upwards for a year.

This mixture contains 7 grains of calcareous earth; and, from a subsequent experiment, I guess it to contain as much fixed air, as there is in 14 grains of calcareous earth.

Experiment VIII.

Least it should be supposed, that the reason why the earth was not precipitated in the foregoing experi-

ment, was, that it was not furniſhed with a ſufficient quantity of fixed air, the following mixture was made, which contains the ſame proportion of earth as the former, but a leſs proportion of fixed air: $4\frac{3}{4}$ ounces of the above-mentioned water, containing fixed air, were diluted with $6\frac{1}{4}$ of rain water, and then mixed with $6\frac{1}{2}$ ounces of limewater. A precipitate was immediately made on mixing, which could not be re-diſſolved on ſhaking.

Experiment IX.

I made ſome experiments to find whether the unneutralized earth could be precipitated from other London waters, by the addition of lime water, as well as from Rathbone-place water. It is neceſſary for this purpoſe, that the quantity of lime water ſhould be adjuſted very exactly; for, if it is too little, it does not precipitate all the unneutralized earth; if it is too great, ſome of the earth in the lime water remains ſuſpended. For this reaſon, as I found it almoſt impoſſible to adjuſt the quantity with ſufficient exactneſs, I added ſuch a quantity of lime water, as I was well aſſured, was more than ſufficient to precipitate the whole of the unneutralized earth; and when the precipitate was ſubſided, decanted off the clear liquor, and expoſed it to the open air, till all the lime remaining in the water was precipitated, by attracting fixed air from the atmoſphere. The clear liquor was then decanted and evaporated, which is much the moſt exact way I know of ſeeing whether any unneutralized earth remains ſuſpended in the water. The reſult of the experiments was as follows:

200 ounces of water, from a pump in Marlborough-ſtreet, were mixed with 38 ounces of lime water. The earth precipitated thereby weighed 38 grains. The clear liquor, expoſed to the air, and evaporated in a ſilver pan till it was reduced to 6 or 7 ounces, depoſited no more than 2 or 3 grains of unneutralized earth.

A like quantity of the ſame pump water, evaporated by itſelf without the addition of lime water, depoſited about 19 grains of unneutralized earth.

200 ounces of water, from a pump in Hanover-ſquare, being mixed with 67 ounces of lime water, the precipitate weighed 93 grains. The clear liquor, treated in the ſame way as the former, depoſited about 2 grains of earth. 200 ounces of the ſame water, evaporated by itſelf, depoſited 28 grains of earth.

The ſame quantity of water from a pump in St. Martin's church-yard, being mixed with 82 ounces of lime water, the precipitate weighed 108 grains. The clear liquor depoſited ſcarce any unneutralized earth on evaporation.

The ſame quantity of water, evaporated by itſelf, yielded 45 grains of unneutralized earth.

The way, by which I found the quantity of unneutralized earth depoſited on evaporation, was, after having decanted the clear liquor, and waſhed the reſiduum with rain water, to pour a little ſpirit of ſalt into the ſilver pan, which diſſolves all the calcareous earth, but does not corrode the ſilver. Then, having ſeparated the ſolution from the inſoluble matter, the earth was precipitated by fixed alcali.

In this way of finding the quantity of unneutralized earth, care muſt be taken to add very little more acid

acid than is neceſſary to diſſolve the unneutralized earth, and to uſe as little water in waſhing out the ſolution as poſſible; for otherwiſe a good deal of the ſelenite, which is depoſited in the evaporation of moſt water, will be diſſolved; the earth of which will be precipitated by the fixed alcali, and by that means make the quantity of unneutralized earth appear greater than it really is.

It appears from theſe experiments, that the unneutralized earth is intirely precipitated from theſe three waters, by the addition of a proper quantity of lime water; as the trifling quantity found to be depoſited, on the evaporation of two of them, moſt likely proceeded only from not expoſing the water to the air, long enough for all the lime to be precipitated. So that I think it ſeems reaſonable to conclude, that the unneutralized earth, in all waters, is ſuſpended merely by being united to more than its natural proportion of fixed air.

To return to Rathbone-place water; it appears from the foregoing experiments, that one pint of it, or 7315 grains, contains, firſt, as much volatile alcali as is equivalent to about $\frac{9}{10}$ grains of volatile ſal ammoniac: ſecondly, 8 $\frac{4}{10}$ grains of unneutralized earth, a very ſmall part of which is magneſia, the reſt a calcareous earth: thirdly, as much fixed air, including that in the unneutralized earth, as is contained in 19 $\frac{8}{10}$ grains of calcareous earth: fourthly, 1 $\frac{2}{10}$ of ſelenite: fifthly, 7 $\frac{9}{10}$ of a mixture of ſea ſalt, and Epſom ſalt; and the whole ſolid contents of 1 pint of the water is 17 $\frac{1}{2}$ grains.

One pint of water, from the pump in Marlborough-ſtreet, contains 1 $\frac{4}{10}$ grains of unneutralized

earth, and as much fixed air as is contained in 2 $\frac{9}{10}$ grains of calcareous earth.

The ſame quantity of water, from the pump in Hanover-ſquare, contains 2 $\frac{1}{10}$ grains of unneutralized earth, with as much fixed air as is contained in 7 $\frac{2}{10}$ of earth.

The ſame quantity of water, from St. Martin's Church-yard, contains 3 $\frac{4}{10}$ grains of unneutralized earth, with as much fixed air as is contained in 8 $\frac{2}{10}$ of earth.

Received November 18, 1766.

XII. *Deſcription of a Meteor ſeen at* Oxford, October 12, 1766. *In a Letter to* Charles Morton, *M. D. Sec. R. S. from the Rev.* John Swinton, *B. D. F. R. S. Member of the Academy* degli Apatiſti *at* Florence, *and of the* Etruſcan *Academy of* Cortona *in* Tuſcany.

Dear Sir,

Read Feb. 26, 1767.

THE Reverend Dr. Sharp coming into Chriſt-Church common-room out of the great quadrangle, on Saturday, October 12, 1765, about 8^h 30′ P. M. informed the company there, that he had ſeen ſome remarkable *Auroræ Boreales* a few minutes before. But, as ſuch phænomena